SUBSYSTEM FOR FAST DIGITAL FEEDBACK AT NSLS

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Abstract

A fast digital feedback system has been installed in the UV ring at the National Synchrotron Light Source facility and is in operation. A similar system is being developed for the X-ray ring. The micro subsystem is VME-based and uses fast ADC boards to sample the orbit. Corrections are computed and the resulting kick values are sent to the correctors (trim magnets) at 5 kHz through DACs. The subsystem uses the standard real-time Control Monitor [1] developed at NSLS and can accept commands from the high-level workstations. However, during the feedback operations, there is minimal intervention from the rest of the control system. The system provides a bandwidth of ~200Hz (@DC gain 100) and reduces the vertical drift to a small fraction of the beam size. This paper focuses on the architecture of the system and software strategies employed to achieve the 5 kHz rate. For diagnostic purposes, the software stores the orbit and the kick values in the CPU memory in a ring buffer. This data can be retrieved, analyzed and displayed in time and frequency domains[1].

1 INTRODUCTION

The NSLS facility has two storage rings, one for UV and one for X-ray. To improve the orbit stability, analog local feedback systems in the X-ray ring insertion device beam lines and analog global feedback systems for both rings were installed in the early 90's and have been in operation since. These systems provide an order of magnitude reduction in orbit motion. Though successful, the analog hardware cannot easily be modified to experiment with various correction algorithms or different selection of BPMs (Beam Position Monitors) and trim magnets in the rings. Hence a prototype digital system was set up for the X-ray ring and its performance was studied.

The system used two of the existing micros (orbit and trim micros) in the control system. The orbit micro samples the BPM signals at 550 Hz and stores the data in an off-board memory. The trim micro is used by the operators to control and monitor the trim magnet power supplies. A separate micro was installed for computer-intensive feedback calculations. This micro shared the memory with the orbit and trim micros via the bit-3 memory adapter boards [2]. The results of the

prototype system were encouraging. However, the bandwidth was small compared to the analog system due to the slow sampling rate.

To match the bandwidth of the analog system, the sampling rate should be at least 30 to 50 times the desired bandwidth. Use of fast digitizers at the BPM end and a second processor in the trim micro could improve the system. This would entail major changes in the electrical cabling and extensive software upgrades to the existing micros. Since the rings are operational most of the time with minimum downtime for maintenance, this is not a viable option. The decision was made to install dedicated micros with minimum modifications in the electrical configuration.

2 HARDWARE CONFIGURATION

Three systems have been implemented, one for the UV ring and two for the X-ray ring (horizontal and vertical planes). These are VME-based microprocessor systems consisting of three standard boards (a CPU, a General Purpose Light Source board and a non-volatile memory) to run the NSLS Control Monitor software and additional I/O boards specific for the digital feedback. The CPU board is a Motorola 2300 series single board computer with 32 Mbyte of DRAM and a 604 PowerPC running at 330 MHz.

For digitization of the orbit signals, VMICVME-3123 ADC boards from VMIC Corporation are used. Each board has 16 differential input channels, each with its own sample-and-hold amplifier and 16-bit A/D converter. It is capable of digitizing all 16 channels simultaneously up to 100 kHz. The board has a dual port memory (DRAM) capable of holding 1 sample to 1 Mega samples of digitized data. The DSP on the board applies gain and offset corrections to the digitized data using the values stored in DSP memory before depositing the data in the DRAM. The feedback corrections are output to VMICVME-4116 DAC boards. Each board has 8 channel D/A converters with 16-bit resolution. The settling time is 10 μsec.

The UV ring has 24 BPMs and 16 trims for each plane and the feedback micro has 3 ADC and 4 DAC boards. The X-ray ring has 48 BPMs and one more signal from a photon beam position detector. The number of trims for vertical is 40 and for horizontal 56. Hence the micro has 4 ADC and 7 DAC boards for the horizontal plane and 4 ADC and 5 DAC boards for the vertical plane.

Prior to the implementation of the digital feedback system, buffer amplifiers were used to split the BPM

signals among the orbit micro, analog global feedback and local feedback systems. Each amplifier can handle 4 BPM signals. To route the orbit signals to the digital feedback micro without extensive cabling work and without impacting the operational micros, a second buffer amplifier is interposed between the BPM receivers and the existing buffer amplifier. The correction signals from the analog and digital systems and the DAC outputs from the trim micro are output to a summing junction. (see Fig. 1). During the development period, one can switch easily from the analog to the digital system or vice versa by disconnecting the cables.
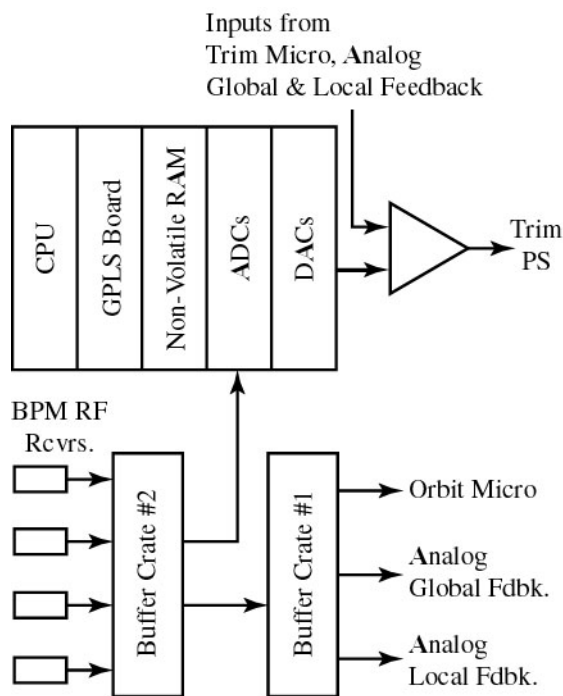

Figure 1: Hardware configuration.

3 SOFTWARE

3.1 Overview

The micro is driven by the same real-time software executed by other micros in the facility. The software uses the real-time VxWorks operating system and provides a standard interface to the high-level workstation programs. The application modules control the hardware and software functions that are specific to a micro. These modules are plugged into the Control monitor software and loaded into the micro. The digital feedback software has logical devices for feedback control and status monitoring. Array devices are also set up for storing data blocks used for the digital feedback correction. Prior to turning the

feedback on, high-level software loads a configuration block (specifies the list of disabled BPMS, number of eigenvector and correctors, feedback filter coefficients, feedback gain etc), eigen values, eigenvectors, and reference orbit into the micro. The feedback cycle consists of data acquisition from the BPMs, calculation of the corrections for the trims and data output to the DACs. It is implemented at the highest VME bus interrupt level, generated by the ADC board (see next section). When the feedback is on, there is minimal intervention from the rest of the control system. The frequency of the network messages for status and heartbeat monitoring is usually small and does not have any significant effect on the feedback cycle time.

3.2 Data Acquisition Strategy

At start up, the CPU initiates the calibration mode, during which the gain and offset corrections are generated for each channel and stored in the DSP memory. At the end of calibration, the other parameters are configured. Sampling clock source is internal. To synchronize the sampling of all the ADC boards, they are configured to operate in the multi-board mode and the sample clock signals at the front panel TTL level input are bussed across all the boards. The first board is programmed as a master and the others as slaves. The master mode configures the hardware to drive the same clock signal out of the connector for use by slaves. The slave mode configures the hardware on the board to receive the clock from the master via the connector.

The board provides two modes for the digitization of the signals: 1.Transient Capture mode and 2. Continuous Sampling mode. The first mode cannot be used because of the inherent delays (~1.27 milliseconds) at the start and end of the capture. In the second mode, the data is stored sequentially starting from the beginning of the DRAM buffer. The buffer size is pre-programmed by the host. Once the buffer fills up, it rolls over and starts filling up again. The host has to read the data before it is overwritten. A Halt command can be used to stop the sampling but this will place the board in idle mode causing time delays.

The following software scheme is employed to achieve the 5 kHz rate. The board is sampled at 10 kHz which is twice the desired rate and the buffer size is set to 64 bytes to store 2 sets of samples. When the ADC interrupts are enabled, the board generates a VME bus interrupt when the buffer is **half full** or **full.** The interrupt routine queries the status to determine the cause of the interrupt. When the **half full** interrupt is asserted, the ADC data is moved from the DRAM to CPU memory using 32-bit transfer. It takes 1 μs to transfer 1 sample. The CPU has a window of 100 μs. before the first set is overwritten. After data transfer, the feedback algorithm is executed in the same

interrupt routine. The buffer **full** interrupt waits until the CPU relinquishes the earlier one. The CPU discards the data in the second half of the buffer. To ensure that the digitization is complete for all the boards, the last board in the chain is set up for the interrupt.

3.3 Feedback Software

The singular value decomposition (SVD) algorithm is used for the orbit correction. The difference between the measured and the reference orbits is filtered and then decomposed in the orbit eigen space to obtain the projections of the difference orbit on a pre-specified number of eigenvectors. In the corrector eigen space, the kick values for the correctors are constructed along the corresponding correctors' eigen vectors using these projections. Too many eigenvectors can lead to an unstable system, while too few eigenvectors would compromise the correction. For the UV ring, 24 BPMS, 8 trims and 8 eigenvectors are used. The time taken for the feedback cycle is 138 µs. For the X-ray ring, we are trying various configurations. While running with all the BPMs and the trims enabled, the system allows us up to 12 eigenvectors before we run into the CPU constraints. The trim corrections are output to the respective DAC channels. The data is latched simultaneously at the output of the DACs by a software strobe.

3.4 Diagnostic Utility

To provide diagnostics, the orbit data and the trim corrections are stored in a double-buffered ring buffer. The buffer is set up to hold 1 seconds worth of data at 5 kHz. The duration can be easily increased up to 3 seconds with the available memory. The buffers can be switched from one to the other by a command from a workstation or by an external hardware interrupt generated as a result of beam dump. When a client from a workstation requests the data, the Server in the micro will pass the data from the buffer that is not currently active, thus preserving the integrity of the data. The LAN activity does not produce any noticeable increase in the feedback cycle time while retrieving the data. Analysis of the data in frequency and time domain can help one to diagnose the problems causing the orbit instability. Fig.2 is a Fourier transform of the orbit data (top) and the trim data (bottom) plotted as a function of frequency. The top plot indicates some orbit disturbance at 22 Hz. In the trim plot, one can easily locate this disturbance. It is evident that trims around #10 are driven the hardest in correcting the orbit. In this case the orbit disturbance was due to the Elliptically Polarized Wiggler, which is located between the trims 10 and 11 and is typically

running at 22 Hz. At the time of studies the EPW orbit compensation system went out of regulation.
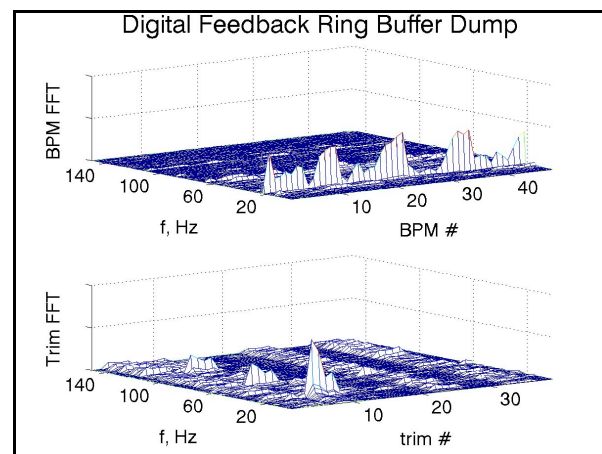

Figure 2: FFT Plot of Orbit and Trim Data

4 RESULTS

The digital feedback micro has been in operation for almost a year in the UV ring. At DC gain of 100, the low frequency noise is practically eliminated. At 60 Hz power line frequency and its harmonic 120 Hz, the reduction in noise factor is 3.5 and 1.5. [3]. The bandwidth is better than the analog system. A significant reduction of the slow orbit drift over a 5 hour-fill is also observed. For the X-ray ring, studies indicate better corrections of the orbit noise as compared to the analog system. The digital feedback for the X-ray ring will be operational soon.

5 ACKNOWLEDGEMENTS

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